Wake Vortex Avoidance System (WakeVAS) Concept of Operations

VAMS Technical Interchange Meeting
15 January 2003

David Rutishauser
Crew Systems Branch, Airborne Systems Competency
NASA Langley Research Center MS 156A
Hampton, VA 23681-2199
(757) 864-8696
d.k.rutishauser@larc.nasa.gov

Separation Rules [1]

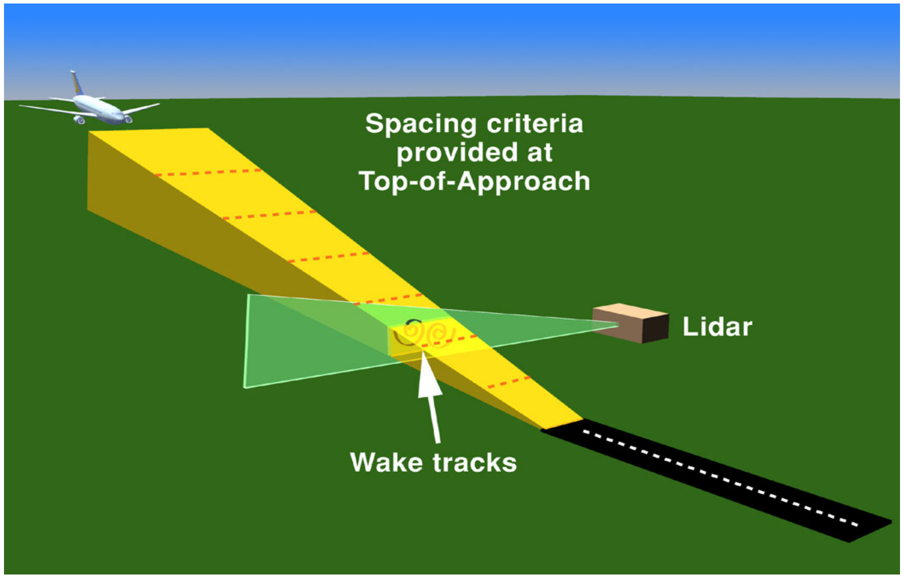
Terminal Configuration >	Single Runway; Parallel Runways < 2500' separation	Intersecting Runways
Departures	Behind B757 or Heavy – 2 min hold; 3 min if intersection or opposite direction same runway, OR Radar separation minima 1. Heavy behind heavy- 4mi 2. Large/Heavy behind B757 –4mi 3. Small behind B757 – 5mi 4. Large behind heavy – 5mi 5. Small behind heavy – 5mi For pairs not listed the separation is 3 miles	2min behind B757 or heavy departure or landing if projected flight paths will cross; includes parallel runways more than 2500' in separation if will fly through the airborne path of other aircraft
Arrivals	Radar separation minima (at threshold): 1. Heavy behind heavy- 4mi 2. Large/Heavy behind B757 –4mi 3. Small behind B757 – 5mi 4. Large behind heavy – 5mi 5. Small behind large – 4mi 6. Small behind heavy – 6mi For pairs not listed the separation is 3 miles, except 2.5 miles in cases when 50 second runway occupancy time is documented Non-Radar Minima: 2 min behind Heavy/B757 except for small follower, 3 min	2 min for aircraft arriving after a departing or arriving Heavy/B757 if arrival will fly through airborne path of other aircraft

Current Separation Rules

- Wake separation rules are static, based on empirical measurements, and represent a response to worst-case persistence of wake hazard
- Over 30 years of wake research and the technologies demonstrated in AVOSS have produced the potential for a dramatic increase in knowledge about the persistence of wake hazard
- Introduction of systems and procedures that utilize this improved knowledge of wake hazard durations will allow for increases in capacity

Background: NASA Aircraft VOrtex Spacing System (AVOSS)

- Goal:
  - Demonstrate an integration of technologies to provide weather-dependent, dynamic aircraft spacing for wake avoidance
  - Operate real-time in a relevant environment
- System demonstrated at Dallas Fort-Worth Airport in July 2000; Represented the culmination of six years of field testing, data collection, and technology development



Products of the AVOSS Program

- AVOSS effort represented the most comprehensive wake and weather data collection effort to date
  - Over 10,000 wakes measured with relevant ambient weather parameters captured
  - Measurements collected at three locations over the course of six years
- AVOSS provided platform for subsystem development & integration
  - Major progress made in wake modeling and sensing
  - Weather subsystems were integrated in new ways and data fusing algorithms were developed
- Demonstration of concept for system integration
  - Example guides future operational concept development

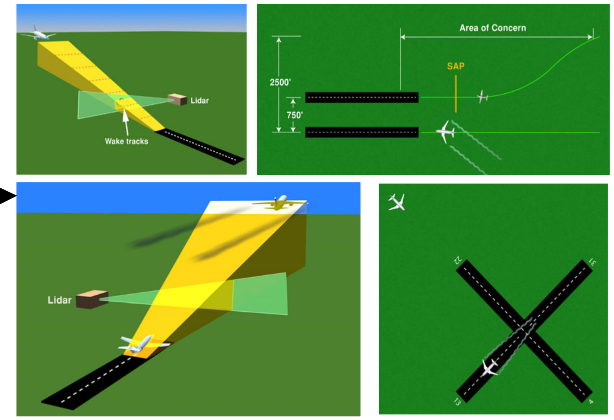
CONOPS Development

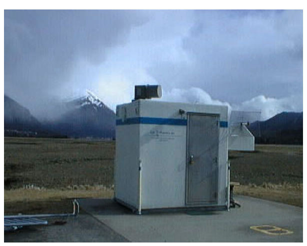
Real-Time Wake Hazard Knowledge

- Weather sensing and prediction
- Wake hazard predictions
- Wake sensing

Procedures/Rules

Interfaces





- Controller Tool
  - Passive
  - Active
- Flight Deck
  - Intuitive Displays
  - NAV/Guidance Integration

- Ground System
- Airborne System
- Hybrid System

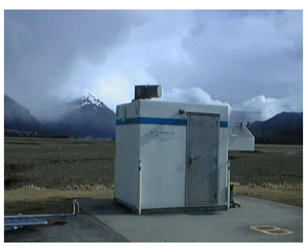
CONOPS Core Ideas

- Utilize hybrid of ground-based and airborne systems to gain dynamic knowledge of wake hazards
- System required to provide accurate wake hazard durations, controllers use hazard information to modulate spacing
- Information also provided to pilots of appropriately equipped aircraft to enhance situational awareness

WakeVAS CONOPS

Real-Time Wake Hazard Knowledge

• Airport weather system augmentations; ground sensors and link to aircraft; wake prediction algorithm



Procedures/Rules

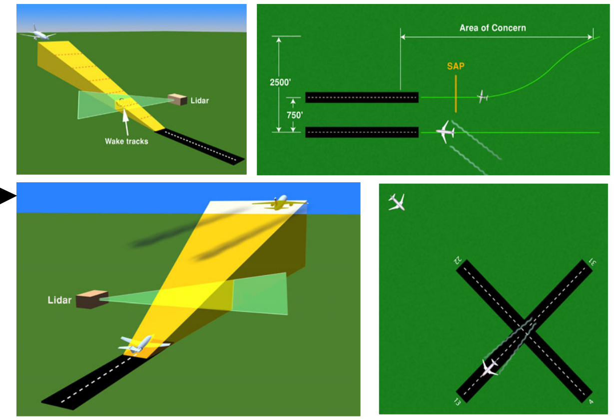
Interfaces

• Controller Tool (responsible for spacing)

- **• coarse**
- **• fine**

• Flight Deck (increase SA)

- **• Intuitive Displays**
- **• NAV/Guidance Integration**



• Hybrid System

CONOPS Cont.

- Roles/responsibilities
  - System provides wake-safe spacing recommendations
    - Coarse: Determination of wakes factor/no-factor and duration
    - Fine: wake spacing transparently integrated into approach spacing tool
  - Controllers responsible for implementing system spacing/separation
  - Pilots of adequately equipped aircraft have wake hazard regions defined and displayed for SA
    - Requires two-way aircraft-ground data link
    - Wake locations not shown, just wake-safe, wake-unsafe regions
    - Will aid in visual approach operations
    - Approach spacing tools will reduce variance and maximize benefit

CONOPS Architecture

- Airport weather system augmented with wake and weather sensors and prediction algorithms
  - Wake algorithm provides probabilistic wake behavior output
  - Terminal Area Planetary Boundary Layer Prediction System (TAPPS) - like microscale weather prediction for wake hazard durations [2]
  - Fusing algorithm combines sensor data and closes a feedback loop between wake and weather predictions and measurements

CONOPS Cont.

- Appropriately defined region of protected airspace for runway configuration and operation targeted (single runway or multi-runway complex; approaches and departures)
- Closed-Loop prediction system senses current conditions diverging from predictions and adjusts to more conservative spacing and changes prediction of duration appropriately

Research Questions

- Accuracy/performance of all subsystems (wake/weather sensors)
- Development of probabilistic wake predictor
- Temporal and Spatial variation of relevant weather parameters (weather sensor placement and coverage)
- Safety analysis; rare event quantification
- Definition of wake hazard strength
- Quantification of weather prediction duration
- Quantification of dynamic spacing impacts on NAS
- Pilot/Controller workloads/display designs
- Data link requirements
- High resolution weather data

Changes/Requirements

- Policy changes
  - Amend current wake separation rules to incorporate dynamic, technology-dependent spacing
  - Consensus on wake hazard definition
- Infrastructure Requirements
  - Standards for aircraft weather data
  - Airport weather suite upgrade
  - Communication link message/bandwidth requirements

WakeVAS Concept
Self-evaluation Approach and Process [3]

- Define solution space
  - Initial airport set
  - Inherent operational attributes
- Define analyses and scenarios
  - Correlate specific airports with their indigenous operational attributes
  - Capture maximum solution space coverage and aircraft operations
- Analysis and Results
  - Capacity and air traffic flow impacts and sensitivities at local, regional, and national system-level
    - RAMS Simulation Tool -- local and regional
    - AwSIM/Draper Simulation Tool -- enroute and national
- Refine and extend solution space and analyses
  - Add airports to simulation based on the characteristics of the reference set of initial airports
  - Extrapolate capacity and air traffic flow results to analyze
  - economic impacts

WakeVAS Concept Solution Space

Airport Parameter	Environment	Aircraft	NAS-level	Subsystem-level
Single runway	Frequency of Instrument/ visual operations	Approach/ Departure speeds	Traffic mix/schedule	Subsystem performance and requirements
Multi-runway	Prediction input parameters	Climb gradients	Dynamic spacing impacts	Wx prediction horizon
Noise Impacts	Seasonal/ diurnal variations of wx	Operational weights	Efficiency gains	Human performance
Traffic mix/ schedule	Geographic climatology	Equipage rates	Contingency operations	Interfaces
Equipment mix	Discrete events (fronts, convective)	FAA Weight Category		
Local procedures, constraints				
Capacity limits/ source				

Partial WakeVAS Evaluation Matrix [4].

Airport	ATL	BOS	DFW	EWR	LAX	LGA	ORD	SFO	JFK	MIA	MEM	CLT
Configuration	2 pair Closely Spaced Parallel Runways (CSPRs)	CSPR & Int.	2 pair CSPRs	CSPR & Int.	2 pair CSPRs	Int.	Int.	2 pair CSPRs	2 pair indep	1 pair indep	1 pair CSPRs & Int.	1 pair indep & int.
Operation to Test	Single-rwy Arr. & Dep.	CSPR & Int. Arr. & Dep.	Single-rwy Arr. & Dep.	CSPR & Int. Arr. & Dep.	CSPR Arr. & Dep.	Int. Arr. & Dep.	Single-rwy & Int. Arr. & Dep.	CSPR Arr. & Dep.	Single-rwy Arr. & Dep.	Single-rwy Arr. & Dep.	CSPR & Int. Arr. & Dep.	Single-rwy & Int. Arr. & Dep.
% B757 & Heavy	22	13	11	12	21	9	10	25	31	12		
% hours below VMC for CY2000	35	34	31	22	55	25	39	49	28			

References

1. *Air Traffic Controller's Handbook,* FAA Order# 7110.65N.
2. Kaplan, Michael L.; Lin, Yuh-Lang; Charney, Joseph J.; Pfeiffer, Karl D.; Ensley, Darrell B.; DeCroix, David S.; and Weglarz, Ronald P.: *A Terminal Area PBL Prediction System at Dallas-Fort Worth and its Application in Simulating Diurnal PBL Jets*, Bulletin of the American Meteorological Society, Vol. 81, No. 9, September 2000.
3. R. Yackovetsky, Airspace Systems, Concepts and Analysis Competency, NASA LaRC.
4. Cooper, W., Levy, B., Lunsford, C., Mundra, A., Smith, A.; *An Evaluation of Selected Wake Turbulence ATC Procedures to Increased System Capacity,* MITRE CAASD report delivered to the FAA, Enclosure to F064-L-015, 28 June 2002.